Understanding and Assessing Global Ocean Carbon Sequestration

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RESEARCH OBJECTIVES

Over the past century and a half, atmospheric CO_2 concentrations have risen by over 30% from pre-industrial levels. The increase is approximately half the cumulative emission as a result of human activity, with the oceans acting as a major repository for the anthropogenic carbon. This rapid increase in the atmospheric CO_2 has contributed in some measure to the recent warming trends observed worldwide. Understanding the processes that maintain and change the carbon cycle, and developing strategies for managing carbon fluxes and inventories, are national priorities. The following questions are critical: *How does the ocean naturally sequester carbon? How will this change in the future? Could purposeful enhancement of carbon storage in the ocean be an effective way to manage CO_2 in the atmosphere and are such actions safe?*

Biological transformations of carbon in the sea have an important impact on the atmosphere. Marine phytoplankton, whose biomass is renewed entirely every 1 to 2 weeks, consume CO_2 through photosynthesis at a rate of ~50 Pg C yr^{-1} and transport ~10 Pg C yr^{-1} from the surface layer to the deep sea. These fast biological and equally fast physical processes alter the CO_2 distribution in the surface ocean and atmosphere. If we were to disable the "biological carbon pump," then levels of atmospheric CO_2 would rise by 30%. The challenge is to follow such fast processes on a global scale.

Figure 1. Carbon Explorer just prior to deployment in the North Atlantic Ocean by Jim Bishop. UC Berkeley Graduate student Phoebe Lam assisted. The fully robotic float measures temperature, salinity, pressure, particulate organic carbon biomass, light scattering, and carbon sedimentation during its daily transits from kilometer depths to the surface. Data are transmitted to shore in real time for the greater part of one year.

APPROACH

The international project, Argo, is seeding the ocean with thousands of low-cost, long-lived autonomous profiling floats for studying the variability of heat, salinity, and mid-depth circulation of the ocean. Four years ago, we initiated a collaborative effort with Argo scientists to create the first robotic Carbon Explorer—a fully robotic telemetry- and sensor-enhanced version of an Argo float—carrying new optical sensors for characterizing the distribution and fate of marine biology products.

Under Berkeley Lab leadership, Carbon Explorers controlled to cycle between the surface and kilometer depths have been deployed in the subarctic North Pacific (April 2001, February 2003) and in the Southern Ocean surrounding Antarctica (January 2002), where they have remained operational for more than one year in notoriously stormy seas. Three more have just begun observations in the North Atlantic (June 2003).

ACCOMPLISHMENTS

Our North Pacific Carbon Explorers documented the response of marine biota to an iron-deposition event associated with a massive dust storm originating in northeast Asia (Bishop, Davis, and Sherman, 2002).

In the Southern Ocean, Carbon Explorers have quantified an immediate biomass enhancement in response to deliberate iron amendment (Bishop et al., 2002). Also, for the first time, they have documented carbon exported from such experiments into the deep sea. Results have been submitted for publication.

SIGNIFICANCE OF FINDINGS

The development of the Carbon Explorer has truly revolutionized the study of ocean biogeochemistry, by opening an entirely new path for ocean carbon cycle understanding. We have proven an inexpensive method for following biological processes in the ocean, on daily time scales, for the greater part of one year. No limitation prevents implementation of sensors for other carbon components and fluxes on the Carbon Explorer.

The Explorers are inexpensive enough for wide deployment in the oceans to follow the natural carbon cycle. They can also perform observations during small-scale experiments, such as those designed to study ocean ecosystem response to ocean fertilization.

RELATED PUBLICATIONS

Bishop, J.K.B., R.E. Davis, and J.T. Sherman, Robotic observations of dust storm enhancement of carbon biomass in the North Pacific. Science, 298, 817–821, 2002.

Bishop, J.K.B., T.J. Wood, and J.T. Sherman, Carbon Explorer assessment of carbon biomass variability and carbon flux systematics in the upper ocean during SOFeX. EOS Trans Am Geophys Union, 83(47), F799, 2002.

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